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Exploring 6th to 8th graders' math play processes and strategies

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Abstract: Students' math problem-solving processes and strategies during math gameplay are poorly understood given its complexity. This ethnographic study examined gameplay sessions with 150 students over nine months in three design-based implementations. Findings revealed three preliminary patterns: 1) students' explanatory math play developed overtime; 2) students' cognizance to make sense of math in real-world context; and 3) students managing struggles to be productive.

Introduction and background

Math problem solving is complicated. Prior research has demonstrated that digital game-based learning (DGBL) environments can be effective platforms for doing math (Tokac et al., 2019). In DGBL, when working on in-game tasks, learners are naturally engaged in exploratory- and discovery-oriented problem solving. Game mechanics, game rules, and game tasks can facilitate learners to generate, test, and experiment hypotheses during the math problem solving processes (Ke et al., 2019). These processes are complicated and can be arduous and frustrating. *Math play* is a core to learners' engagement in game-based math problem solving; in which learners immersing in iterative rounds of math hypothesis testing and exploration, encompassed by failure or struggle (Williams-Pierce & Thevenow-Harrison, 2021). During *math play*, learners gradually develop problem-solving skills and epistemological sense toward math—by reorganizing and building up experience and by integrating new information into knowing (Kolodner, 1983). Notably, productive struggle is an important component in *math play*. Warshauer (2015) illustrated four types of struggles in middle school math classrooms: 1) get started, 2) carry out a process, 3) uncertainty in explaining and sense-making, 4) express misconception and errors.

Although research in the learning sciences has shed light on the processes of student learning in math (Warshauer, 2015), the processes and strategies that students use while playing math learning games are still vague. This murky area can hinder our understanding and theory development that fully benefit learners when they are engaging in DGBL. The purpose of this study is thus to identify the processes and strategies that middle school students' use during game-based math problem solving. Our focal research question is *what is math play and its associated strategies as perceived and enacted by middle school students in an architectural math game?*

Method

We used an ethnographic method to examine the phenomenon embedded in 6th through 8th graders' math gameplay sessions. The students played *E-Rebuild*, a math DGBL designed based on standardized math concepts for middle school students (Ke et al., 2019). The study is ongoing, we collected data from two schools with seven teachers and their 150 students through nine months long-term ethnographic participation in three design-based implementations. This study used data collected with participatory observations, interviewing, in-field notes, game artifacts, and computer logged gameplay-learning analytics. Multiple data sources ensured trustworthiness through triangulation. Open coding and constant comparative techniques (Glaser & Strauss, 1967) were iteratively conducted to construct meaning of the processes and strategies used by the middle school students during game-based math problem solving.

Results

Students' explanatory math play developed overtime

In the math gameplay-learning trajectories, students often revisit levels that they have successfully completed. Sometimes, students also tried to help other students when other students are dealing with the game math tasks that they have completed before. This iterative process has led to reorganizing and rediscovering for math conceptual development and shaping in students' memory. Students were unsure about the underlying concept related to their solution. But as they iteratively experimented with the same type of problems by trying different acts or solutions, they started to develop conscious perspectives and were able to explicate with math thinking.

For example, in one class, Ryan (pseudonym, 6th grade) was trying to solve a math task focusing on geometry and angle (folding a square-shaped paper to a target 3D shape). He approached the task without math understanding: "*Is that (angle) 45°? Cause it's half of 90...or 40?*" After three failed attempts, he used an in-game learning support and figured out the solution, but he was still pondering about the accuracy of the solution: "*I don't think it will work*." He tried the solution anyway, completed the level, and even earned all the badges. Facilitator ("F" hereinafter): "*Do you know why it is 90°?* Ryan: "*I don't know (smiling).*" After two weeks (five gameplay sessions), he helped a peer with the same level, he put "180°." This time, he failed to help his peer to solve the level. After another three gameplay sessions, Facilitator asked: "*have you learned anything?*" Ryan voluntarily mentioned this level, and was able to explain the embedded math concept by transitioning between gestures and the game interface: "*I learned the angles. It's 90° (using his hand to gesture the folding of a 90° angle).*" Computer-logged task performance data suggested that Ryan has retried and failed at least three more times with this exact level in-between different gaming sessions, until completing the final successful attempt. In this example, Ryan's math play evolved as he experienced gameplay purposefully and mathematically.

Students' cognizance to make sense of math in real-world context

Observations, interviews, and logged data of a student, who has been slacking in in-game task performance and kept gaming the system, revealed that students' meaningful math play occurred when they were cognizant of the math concepts and when they integrated real-world contextual sense-making into gameplay:

1 F: What do you like?
2 Beau (6th grade): Basketball.
3 F: Do you see any math in basketball?
4 Beau: Yes. *The arch.*
5 Other students: That's science.
6 Beau: *That's math*, you need to know *the arch*, get the ball in there.
7 F: Oh nice, did you see any connections between that and this game?
8 Beau: Oh, the basketball level, I painted the basketball court already.
9 F: Is that your favorite level?
10 Beau: Yes.

Students managing struggles to be productive

As observed, students experienced iterative struggles along the math play trajectory, they managed the struggle with diverse strategies. For example, some students were observed to manage in-game struggles *with more careful problem analysis or information processing*; for instance: "Tyson (7th grade) completed a hard level with all the badges. He cheered and thrown his hands in the air in excitement." F: "how did you feel about it?" Tyson: "it was kinda *stressful*." F: "what guided you to the completion of the level?" Tyson: "well, I was trying, and *it was always wrong*, because *I didn't notice* that 85% (discount in purchasing the materials)… I think I just kinda did it."

Discussion and conclusion

In this study, we elucidated the processes of and strategies used by middle school students during math play. The three highlighted preliminary patterns in this study demonstrate the scholarship of math play, reorganization and rediscovery for math conceptual understanding during math play, and strategic, productive struggle management in DGBL (Kolodner, 1983; Warshauer, 2015; Williams-Pierce & Thevenow-Harrison, 2021). We maintain that these patterns are important insights for designing meaningful and constructive game-based math problem-solving experience, or math play, for middle school students.

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